

WRE #349
Technical Memorandum

**STORMWATER RUNOFF AND
POLLUTANT MODEL
(SRPM)**

MODEL DOCUMENTATION

Version 1.3

by

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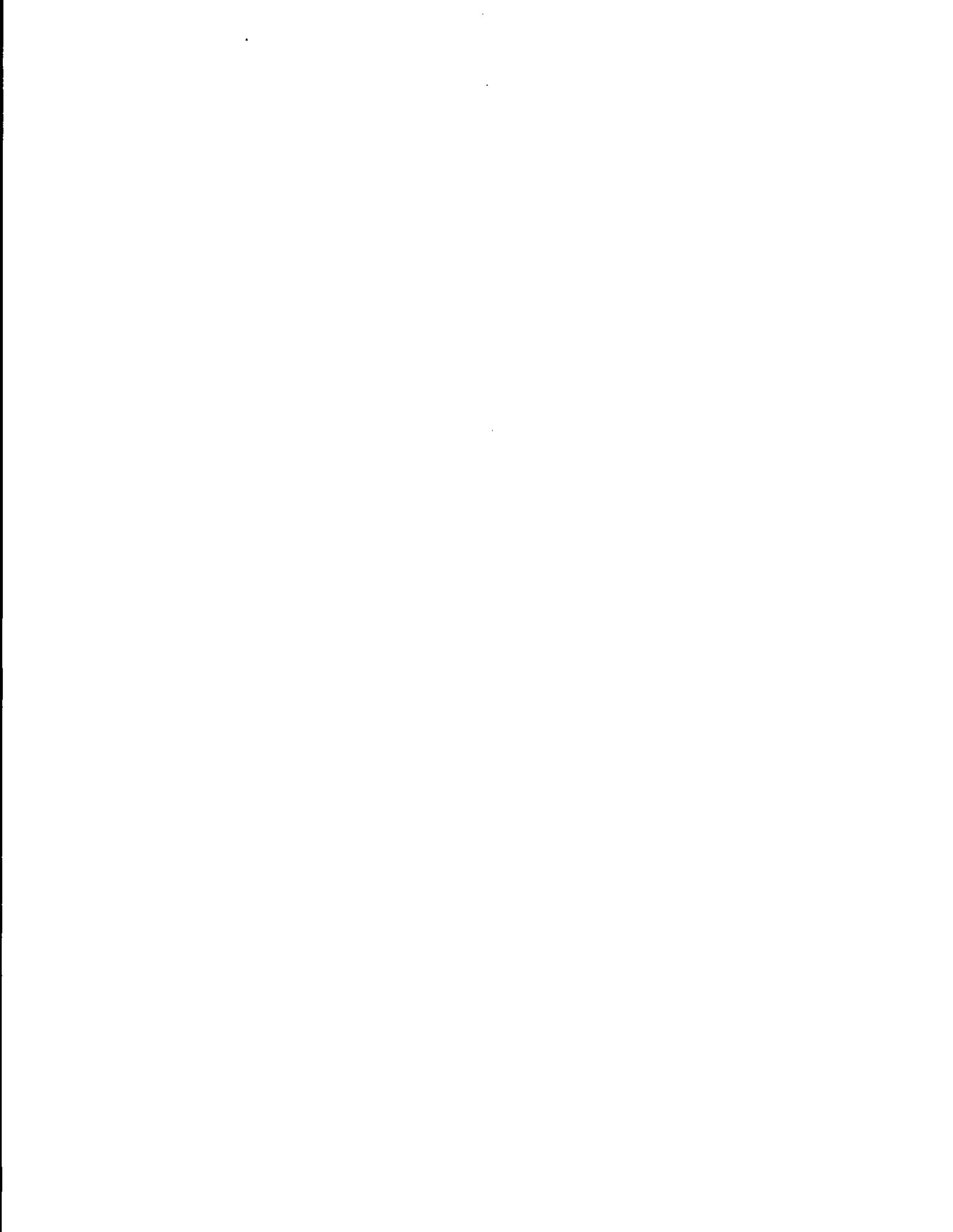


TABLE OF CONTENTS

1. INTRODUCTION	1
2. DESCRIPTION OF SRPM MODEL	4
3. MODEL ALGORITHMS	4
3.1 Hydrology Simulation	4
3.1.1 Overland flow	5
3.1.2 Evaporation	7
3.1.3 Infiltration	7
3.1.4 Flow routing	10
3.2 Water Quality Simulation	11
3.2.1 Buildup	12
3.2.2 Washoff	12
3.2.3 Phosphorus Transpor in Agricultural Areas	13
4. INPUT DATA DESCRIPTION	15
4.1 Meteorological Data	15
4.2 Watershed Data	15
4.3 Pollutant Buildup/Washoff Data	16
5. MODEL OUTPUT	16
5.1 Time Series Output	16
5.2 Other Simulation Outputs	16
6. MODEL PACKAGE	17
6.1 Programs and Input/Output Files	17
6.2 Computer Requirements	18
ACKNOWLEDGMENTS	19
REFERENCES	19
APPENDIX A - SRPM INPUT	
Hourly Precipitation Data	A-1
Hourly Pan Evaporation Data	A-2
Watershed Data and Pollutant Buildup/Washoff Data	A-3



APPENDIX B - FORTRAN PROGRAMS

Program to Convert Daily to Hourly Evaporation Data	B-1
Main Program of the SRPM Model	B-2

APPENDIX C - SRPM OUTPUT

Hourly Runoff and Pollutant Concentrations	C-1
Daily Runoff and Pollutant Concentrations	C-2
Monthly Runoff and Pollutant Concentrations	C-3
Annual Runoff and Pollutant Concentrations	C-4
Hourly Mass Balance Data	C-5
Geometric and Hydraulic Data	C-6

LIST OF TABLES

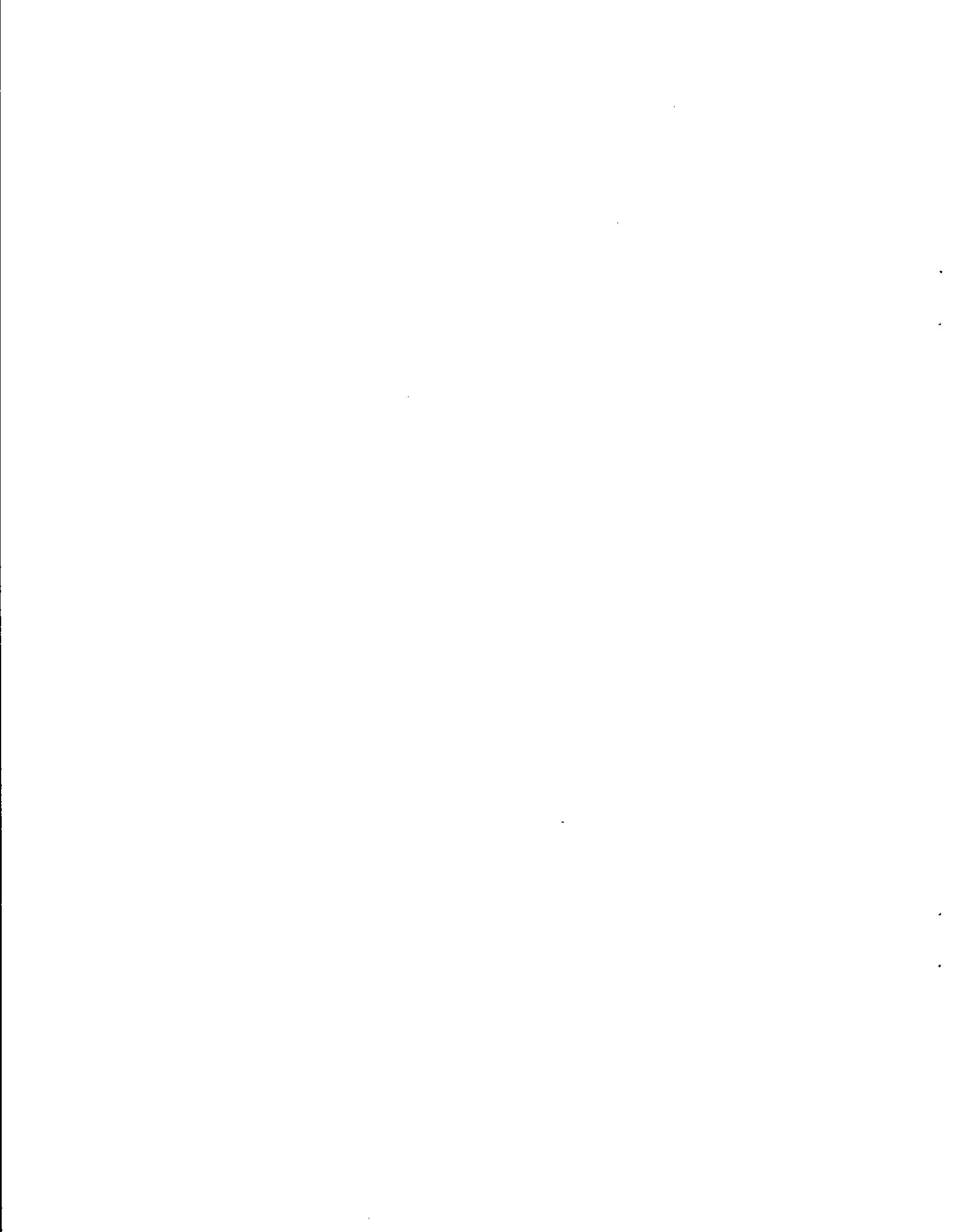
Table 1. Components of SRPM Model Package	17
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1. INTRODUCTION

Stormwater runoff and the associated pollutant loads have gained great attention in urban planning and design. Evaluation of alternative scenarios in urban development is needed to assess the environmental impacts on existing watersheds due to changes in land use. A watershed model is needed for this evaluation and can be used as a tool to predict future water quality impacts on receiving water and to assess urban stormwater management alternatives (Greene and Cruise, 1995). Watershed managers and planners need such a tool to estimate the relative water quality impact of subbasin discharges on downstream locations, which in turn helps to select appropriate watershed-wide stormwater management control alternatives (Shamsi, 1996).

Modeling the quantity and quality of stormwater runoff is difficult due to variation of such factors as land use, human activities, and meteorological conditions (Haster and James, 1994). A few existing watershed models are available to simulate stormwater runoff and its pollutant loads for different applications. The U.S. EPA (1992) defined three classes of watershed-scale models: (1) simple methods; (2) mid-range models; and (3) detailed models. Simple methods apply simplistic, statistical, and/or empirical equations to simulate annual averages of runoff and pollutant loads. These methods require historical monitoring data and their applications are usually limited to the areas for which the models were developed and to similar watersheds (U.S. EPA, 1992). Mid-range models describe the relationship of pollutant loadings to hydrologic and erosion processes on a monthly or seasonal basis. These models consider neither adsorption, degradation and transformation processes of pollutants, nor pollutant transport within and from the watershed (U.S. EPA, 1992). They can be applied for relative comparison analysis for watershed planning decisions. Detailed models simulate the physical hydrologic and pollutant transport and transformation processes in watershed areas at a small time step to account for effects of storm events, such as Areal Nonpoint Source



Watershed Environment Response Simulation (ANSWERS) (Beasley and Huggins, 1981), Distributed Routing Rainfall Runoff Model – Quality (DR3M-QUAL) (Alley and Smith, 1982), Hydrological Simulation Program – FORTRAN (HSPF) (U.S. EPA, 1993), Storage, Treatment, Overflow, Runoff Model (STORM) (U.S. Army Corps of Engineers, 1977), Storm Water Management Model (SWMM) (Huber et al., 1987), and Simulation for Water Resources in Rural Basins (SWRRB) (Arnold et al., 1989). Among these detailed models, ANSWERS and SWRRB were developed for agricultural areas; DR3M-QUAL, STORM, and SWMM were designed for urban areas; HSPF, on the other hand, can be applied to most complex watershed areas.

The HSPF model simulates hydrolysis, oxidation, photolysis, biodegradation, volatilization, and sorption processes to describe pollutant generation, transformation and transport from watersheds to, and within, receiving water bodies (U.S. EPA, 1993). Three distinct categories such as pervious lands, impervious lands, and stream channels are considered in HSPF. The model requires extensive input data, and highly trained personnel and team efforts, so that it is not suitable for the kind of evaluations being considered here.

DR3M-QUAL, supported by the U.S. Geologic Survey, and STORM, developed by the U.S. Army Corps of Engineers, are the detailed urban watershed models. Both models were designed to simulate limited pollutants, which do not meet the requirement of this study to allow users to define water quality constituents to be simulated. On the other hand, the SWMM model developed by the U.S. EPA (Huber et al., 1987) does allow users to specify up to ten pollutants of interest for simulation. However, SWMM also requires extensive input data and modeling effort.

As a part of the *Data Analysis and Modeling of Urban Stormwater Treatment Systems for Water Quality Compliance – Phase Two* project, a Stormwater Runoff and Pollutant Model (SRPM) was developed to simulate urban watershed runoff and the associated pollutant loads. The SRPM model is a simplified version of SWMM, requires minimum input data, and is easier to be



developed for a user-friendly interface with pre- and post- processors. SRPM was designed to link with a stand alone Best Management Practices Assessment Model (BMPAM) (Xue, 1996) and to integrate with a geographic information system (GIS) platform. Most hydrology and water quality simulation algorithms used in SRPM were adapted from the SWMM model. A reservoir flow routing method (Linsley and Franzini, 1964) was used in SRPM to speed up simulation time, instead of using the Newton-Raphson technique, to solve a nonlinear equation for hydrology simulation in SWMM (Nix, 1994). The SRPM model can run under either PC DOS or UNIX environments and provides reasonable simulation results with limited input data.

The objectives of the project "*Data Analysis and Modeling of Urban Stormwater Treatment Systems for Water Quality Compliance - Phase Two*" are: (1) to quantify the probabilities with which category of source and treatment system type will exceed applicable water quality standards as a function of season; and (2) to identify changes in design, operation, or maintenance parameters for each category that will reduce the frequency of occurrence of exceedences to acceptable levels as a function of season. In order to meet these objectives, three sub-projects were proposed: (1) correction and analysis of the SFWMD Stormwater Discharge Permit Database; (2) evaluation of performances of existing stormwater treatment systems; and (3) identification of changes in design, operation, or maintenance parameters to improve stormwater treatment systems.

Modeling tools will be used in the second sub-project to evaluate the performance of existing stormwater treatment systems and to provide necessary information for the following sub-project. The third sub-project will use statistical analysis results and apply calibrated and verified watershed model and BMP model in selected stormwater treatment facilities to identify the changes in design, operation, or maintenance parameters for improving pollutant removal efficiencies of selected stormwater treatment facilities. Recommendations and suggestions based on simulation results will be developed for future stormwater discharge monitoring programs for the Regulation Department.



With the BMP model developed for this project, SRPM can also be used by the Planning Department staff in watershed analysis to assess runoff and water quality impacts on receiving water bodies or downstream watersheds. The model with a GIS interface is a powerful tool to compare various stormwater management alternatives that occur as a result of new development of land uses and/or changes of human activities in a watershed or basin of interest.

2. DESCRIPTION OF SRPM MODEL

SRPM is a basin-scale hydrologic and water quality model which simulates storm-related surface runoff and the associated pollutant loads in a catchment or watershed. It was developed for urban watershed analysis, but can also be applied to other areas such as agricultural areas. The model was written in FORTRAN and can run under both PC DOS and UNIX operating systems.

SRPM is a continuous simulation model with an hourly time step. It can be used for a single storm event simulation or a long term (such as 10 years) continuous simulation. The outputs of simulated runoff, pollutant loads and concentrations are in standard time series ASCII formats that can be directly read by the BMPAM model described above.

An integrated GIS stormwater modeling tool was proposed to fulfill the stormwater modeling project. Due to the further development of linking SRPM and SBMPM with CIS, pre- and post-processors as well as channel/stream flow routines will be developed in the integrated GIS platform.

3. MODEL ALGORITHMS

3.1 Hydrology Simulation

The SRPM model allows users to simulate up to ten (10) sub-catchments in each

application run. Each sub-catchment represents a different land use type or percentage of pervious and impervious areas. The algorithm used in hydrologic simulation is similar to that used in the RUNOFF block in a U.S. EPA supported watershed model, the Storm Water Management Model (SWMM) (Huber et al., 1987). A sub-catchment is treated as a nonlinear reservoir with consideration of the processes of precipitation, evaporation, infiltration, depression, storage and surface runoff. Outflow (i.e. surface runoff) occurs only when water depth in the hypothetical reservoir exceeds the reservoir capacity which is defined by the maximum depression storage (Nix, 1994).

3.1.1 Overland flow

The rational method, Soil Conservation Service (SCS) curve number method, and Manning's equation are three most widely used methods of simulating stormwater runoff volume and peak discharges from watersheds. The rational method is an approximate deterministic model which uses a ratio of runoff to rainfall (runoff coefficient), rainfall intensity, and drainage basin area to estimate the peak flows in a watershed. This method does not consider temporary storage of runoff nor temporal and spatial variation of rainfall (Pilgrim and Cordery, 1993).

With the SCS curve number method, no runoff occurs until rainfall exceeds a specified initial abstraction. This method estimates runoff by utilizing a relationship between rainfall and a curve number. The curve number represents the soil type, land use coverage, hydrologic condition, and management practices of the land surface. The SCS curve number method does not provide accurate simulation results for small storm events, especially when runoff is less than 0.5 inch (Rawls et al., 1993).

Manning's equation is used for the hydrologic simulation in SRPM. The equation calculates overland flow velocity by using the parameters of hydraulic radius, slope, and the Manning roughness constant. The Manning roughness constant represents the land surface



condition and the land use type of a specific sub-catchment. The hydraulic radius is the ratio of the cross-sectional area of flow to the length of the wetted perimeter. The Manning's equation is defined for English units (Lindeburg, 1992) as:

$$v = \frac{1.49}{n} R^{2/3} S^{1/2} \quad (1)$$

where v = flow velocity (ft/s)
 n = Manning roughness constant
 R = hydraulic radius (ft)
 S = slope of overland flow (ft/ft)

Because the depth of water flow is very small in overland flow from watersheds, the wetted perimeter can be approximated by the width of overland flow (Nix, 1994). Thus,

$$R = A_c / W = [W(d - d_p)] / W = d - d_p \quad (2)$$

where A_c = cross-sectional area of flow (ft²)
 W = width of overland flow (ft)
 d = depth of water on the watershed (ft)
 d_p = depth of maximum depression storage (ft)

The Manning's equation can be rewritten as:

$$Q = A_c v = W(d - d_p) * \frac{1.49}{n} (d - d_p)^{2/3} S^{1/2} = W * \frac{1.49}{n} (d - d_p)^{5/3} S^{1/2} \quad (3)$$

where Q is runoff flow rate from a catchment (ft³/s).

3.1.2 Evaporation

Observed pan evaporation records are used for the calculation of water depletion by the process of evaporation in watersheds. Actual evaporation is calculated based on the pan evaporation values by applying an evaporation coefficient. SRPM allows users to provide monthly evaporation coefficients to account for seasonal variations of the evaporation in a watershed. The calculated evaporation is subtracted from precipitation and/or the water stored in the watershed prior to calculating infiltration.

3.1.3 Infiltration

Horton Model

A three-parameter empirical infiltration model, the Horton Model, has been widely used to calculate the infiltration capacity into soil. The Horton model expresses that the infiltration capacity is equal to the maximum infiltration rate at the beginning of a storm event and then is reduced to a low constant rate as the soil becomes saturated (Rawls et al., 1993):

$$f_p = f_\infty + (f_0 - f_\infty) e^{-\alpha t} \quad (4)$$

where	t	= time from beginning of storm (sec)
	t_p	= time at the end of simulation step (sec)
	f_p	= infiltration capacity into soil at $t = t_p$ (ft/s)
	f_∞	= minimum or ultimate infiltration rate (ft/s)
	f_0	= maximum or initial infiltration rate (ft/s)
	α	= decay coefficient (1/sec)

The infiltration capacity calculated by Equation (4) is often less than the actual infiltration capacity because typical values for infiltration parameters are often greater than

typical rainfall intensities. The integrated form of Horton's equation (Huber et al., 1987) was selected in SRPM to solve this problem:

$$F(t_p) = \int_0^{t_p} f_p dt = f_\infty t_p + \frac{(f_0 - f_\infty)}{\alpha} (1 - e^{-\alpha t_p}) \quad (5)$$

where $F(t_p)$ is cumulative infiltration at $t = t_p$ (ft).

The regeneration or recovery of infiltration capacity during dry weather is calculated for continuous simulation by the following equation (Huber et al., 1987):

$$f_p = f_0 - (f_0 - f_\infty) e^{-\alpha_d(t-t_w)} \quad (6)$$

where α_d = decay coefficient for the regeneration curve (1/sec)
 t_w = hypothetical projected time at which $f_p = f_\infty$ on the recovery curve
(sec)

Due to the difficulty of determining the projected time t_w . Equation (6) can not be used directly. However, a combined equation was developed by Huber et al. (1987):

$$t_{p1} = t_p + \Delta t = -\frac{1}{\alpha} \ln [1 - e^{\alpha_d \Delta t} (1 - e^{-\alpha t_{pr}})] \quad (7)$$

where t_{p1} = new value of t_p for next time step (sec)
 t_{pr} = value of t_p at beginning of regeneration (sec)
 Δt = time step (sec)

Thus, the integrated form of Horton's equation can still be used by applying the calculated t_{p1} for the consideration of regeneration of infiltration. For the continuous simulation, t_{p1} will be substituted for t_{pr} and t_{p2} will be substituted for t_{p1} , etc. (Huber et al., 1987).



Green-Ampt Model

A more approximate physical theory utilizing Darcy's law, the Green-Ampt Model, was selected as another option for infiltration simulation in SRPM. The original model was developed for infiltration into a homogeneous soil with excess water at the surface at all time (Rawls et al., 1993). Mein and Larson (1973) modified the model for application of steady rainfall. The Mein-Larson formulation for infiltration rate for steady rainfall is a two-stage model (Huber et al., 1987):

For $F < F_s$:

$$f = R \text{ and}$$

$$F_s = \frac{S * IMD}{\frac{R}{K_s} - 1} \text{ for } R > K_s \quad (8)$$

For $F \geq F_s$:

$$f = f_p \text{ and}$$

$$f_p = K_s (1 + \frac{S * IMD}{F}) \quad (9)$$

where	f	= infiltration rate (ft/s)
	f_p	= infiltration capacity (ft/s)
	R	= rainfall intensity (ft/s)
	F	= cumulative infiltration volume for a storm event (ft)
	F_s	= cumulative infiltration volume required to cause surface saturation (ft)
	S	= average capillary suction at the wetting front (ft)
	IMD	= initial moisture deficit for the storm event (ft/ft)
	K_s	= saturated hydraulic conductivity of soil (ft/s)



3.1.4 Flow routing

Based on the principle of mass conservation, the difference between the inflow and outflow is equal to the rate of storage of water in a reservoir; that is,

$$\frac{dS}{dt} = I(t) - Q(t) \quad (10)$$

where S = storage volume of water (ft^3)
 $I(t)$ = inflow rate (ft^3/s)
 $Q(t)$ = outflow rate (ft^3/s)

Equation (10) is an ordinary differential equation that is not easily solvable. A simple hydrologic method of routing was presented by Chow (1959) and by Linsley and Franzini (1964):

$$\frac{\Delta S}{\Delta t} = I - O \quad (11)$$

or

$$\frac{S_2 - S_1}{\Delta t} = \frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} \quad (12)$$

where ΔS = change in storage of water during routing period (ft^3)
 S_2 = storage in the reservoir at the end of routing period (ft^3)
 S_1 = storage in the reservoir at the beginning of routing period (ft^3)
 Δt = routing period (sec)
 I = average inflow during routing period (ft^3/s)
 I_1 = instantaneous inflow at the beginning of routing period (ft^3/s)
 I_2 = instantaneous inflow at the end of routing period (ft^3/s)
 O = average outflow during routing period (ft^3/s)

- O_1 = instantaneous outflow at the beginning of routing period (ft^3/s)
 O_2 = instantaneous outflow at the end of routing period (ft^3/s)

Equation (12) can be rewritten as the following equation after grouping the unknowns and knowns on the each side of the equation:

$$\frac{1}{2}O_2\Delta t + S_2 = \frac{1}{2}(I_1 + I_2)\Delta t + (S_1 - \frac{1}{2}O_1\Delta t) \quad (13)$$

The variables on the right side of Equation (13) are known for a given time step while the two unknowns O_2 and S_2 on the left side of the equation can be solved after the relationship between O_2 and S_2 is determined. In a reservoir or a storage system, the geometric dimensions of the reservoir and the outflow structure rating data are usually given. Therefore, the relationship of O_2 with S_2 , each of which is a function of storage depth, can be determined (Huber et al., 1987). This reservoir routing method was applied in the storage/treatment simulation routines of the SWMM model and is also used in SRPM for the simulation of flow routing.

3.2 Water Quality Simulation

Water quality simulation in watershed areas is difficult due to the different physical and chemical processes governing the fate and transport of pollutants, the effects of rainfall and watershed characteristics, and the land use practices (Haster and James, 1994). Both regression equations and deterministic models have been used for the simulation of pollutant loads. For SRPM, a deterministic model that includes build-up and washoff components was selected for the simulation of stormwater pollutant loads. The SRPM model can simulate up to nine water quality constituents: (1) biological oxygen demand (BOD); (2) total suspended solids (TSS); (3) total nitrogen (TN); (4) total phosphorus (TP); (5) zinc (Zn); (6) pesticide; (7) tracer; (8) lead (Pb); and (9) copper (Cu).



3.2.1 Buildup

The concept of "Buildup" was first used to model the accumulation of dust and dirt and associated pollutants on urban street surfaces in 1969 (ASCE and WEF, 1992). Thereafter, the buildup concept (as well as the washoff concept) has been included in several watershed models such as SWMM, HSPF, STORM, USGS, and SLAMM. Buildup is defined as the pollutant accumulation during the dry-weather periods between storms. The buildup process is affected by atmosphere deposition, wind erosion, street cleaning, or other human activities. An exponential equation (Huber et al., 1987) used in the SWMM model was selected for the simulation of the buildup of water quality constituents in SRPM:

$$P_{\text{buildup}} = P_{\text{limit}} (1 - e^{-\alpha t}) \quad (14)$$

where P_{buildup} = amount of pollutant accumulation (lbs)
 P_{limit} = maximum value of pollutant buildup (lbs)
 α = pollutant buildup rate (1/sec)
 t = time (sec)

During the continuous simulation, buildup will not occur during the wet-weather time steps unless runoff is less than 0.0005 in/hr (Huber et al., 1987).

3.2.2 Washoff

Washoff is defined as the pollutant removal process associated with runoff during the wet-weather periods of storm events. Similar to the exponential buildup equation, the exponential washoff equation describes the relationship between the initial amount and the cumulative amount washed off during storm events:



$$P_{washoff} = P_{initial} (1 - e^{-kt}) \quad (15)$$

where $P_{washoff}$ = cumulative amount of pollutant which is washed off at time t (lbs)
 $P_{initial}$ = initial amount of pollutant on surface at $t = 0$ (lbs)
 k = coefficient (1/sec)

Since the amount of pollutant remaining in a watershed (P_{remain}) is equal to the difference between the initial amount and the cumulative washoff amount of pollutant, Equation (15) can be rewritten as:

$$P_{remain} = P_{initial} - P_{washoff} = P_{initial} e^{-kt} \quad (16)$$

Because the coefficient k is a function of runoff rate and particle size, it is very difficult to use a single value to represent the pollutant removal mechanism in the real world. By using the average power of runoff over the simulation time step, a modified washoff equation can be derived to overcome this problem (Huber et al., 1987):

$$P_{remain}(t + \Delta t) = P_{remain}(t) e^{-\beta \frac{1}{2} [r(t)^n + r(t + \Delta t)^n] \Delta t} \quad (17)$$

where β = washoff coefficient
 Δt = simulation time step (sec)
 $r(t)$ = runoff rate at time t (in/hr)
 $r(t + \Delta t)$ = runoff rate at time $t + \Delta t$ (in/hr)
 n = washoff power factor

Equation (17) is used in SRPM for the simulation of water quality washoff.

3.2.3 Phosphorus Transport in Agricultural Areas

In order to better describe phosphorus transport mechanisms in agricultural activities,



a phosphorus movement mechanism used in FHANTM was selected in phosphorus simulation with agricultural areas in SRPM (Tremwel, 1992) :

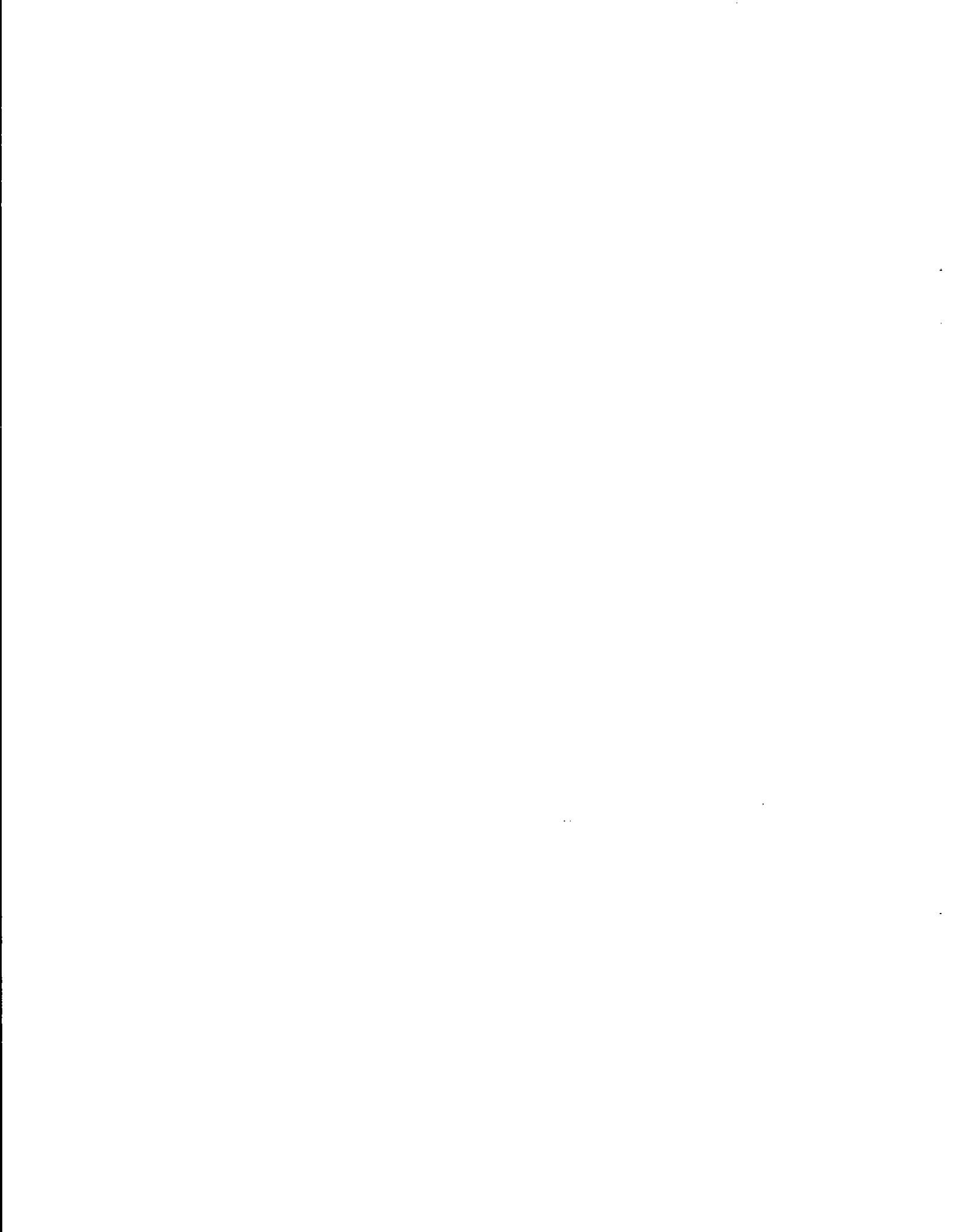
$$P_{\text{water}}(t+\Delta t) = P_{\text{water}}(t) + P_{\text{land}}(t) \Delta t (\alpha I_{\text{rain}} + \beta I_{\text{runoff}}) + CP_{\text{rain}} \Delta t I_{\text{rain}} \quad (18)$$

$$P_{\text{land}}(t+\Delta t) = P_{\text{land}}(t) - P_{\text{land}}(t) \Delta t (\alpha I_{\text{rain}} + \beta I_{\text{runoff}}) \quad (19)$$

where

- P_{water} = mass of phosphorus contained in surface water (kg/ha)
- P_{land} = mass of phosphorus contained in surface land (kg/ha)
- P_{rain} = phosphorus concentration contained in rainfall (mg/L)
- α = effectiveness of rain in removing phosphorus from P_{land} (1/cm)
- β = effectiveness of runoff in removing phosphorus from P_{land} (1/cm)
- I_{rain} = rainfall intensity (cm/hr)
- I_{runoff} = runoff intensity (cm/hr)
- C = converting factor (0.254)
- Δt = time step (hour)
- t = time (hour)

Phosphorus deposition comes from two sources: land and air. In general, animal wastes, fertilizers, or other nutrients introduced by human activities are considered to be land phosphorus deposition, whereas phosphorus in raindrops is considered air deposition. Equation (18) states that phosphorus mass in surface water P_{water} will cumulate with addition of phosphorus mass from raindrops P_{rain} and solubilized portion of phosphorus on surface land. The unsolubilized portions of phosphorus will remain on surface land until next the rainfall or runoff occurs (Equation (19)). Daily phosphorus mass created by animal wastes or fertilizers is added to the phosphorus mass on surface land P_{land} each day (Tremwel, 1992). Equations (18) and (19) were used for phosphorus simulation in agricultural areas. For other water quality constituents, the buildup and washoff equations were still applied for pollutant load calculations.



4. INPUT DATA DESCRIPTION

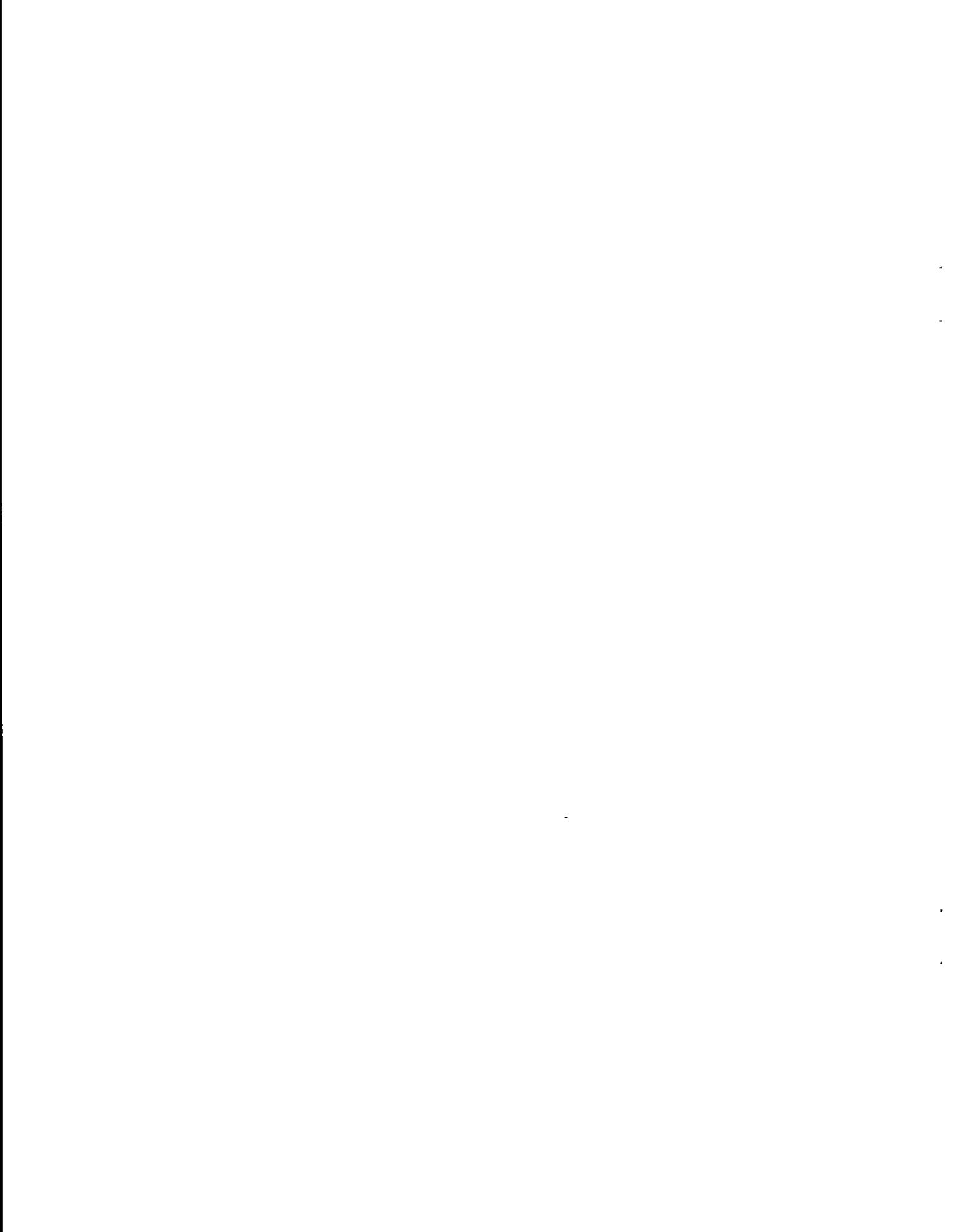
4.1 Meteorological Data

Observed hourly precipitation and hourly pan evaporation records are required for SRPM. Input data formats from these records are illustrated in Appendix A. Units for precipitation and evaporation input data are inches. If the observed hourly pan evaporation data are not available, the daily pan evaporation data can be converted to the hourly evaporation data by using a stand-alone FORTRAN program developed in HSPF model (U.S. EPA, 1993). The source code of the conversion program is provided in the model package (Appendix B).

4.2 Watershed Data

The SRPM model can simulate up to ten (10) subcatchments for each simulation run. The physical characteristics of each subcatchment should be provided to represent each individual basin within a simulated watershed. The required basin characteristic data includes surface area (acres), average width (feet) of overland flow, slope (feet/feet), and infiltration parameters related to soil type of the subcatchment. The infiltration parameters used in the model are the maximum infiltration rate (mm/hour), minimum infiltration rate (mm/hour), decay parameter (1/min), and infiltration regeneration ratio. Infiltration tests are usually required for obtaining these parameters at sites of interest. Users may find these parameters of different soil types in *Handbook of Hydrology* (Rawls et al., 1993) as a starting point of simulation runs. The infiltration parameters may be estimated through calibration. The format of the input watershed data is provided in Appendix A.

Three monthly variation parameters in the model for evaporation coefficient, Manning's roughness, and depression depth (inches) account for the seasonal changes of watershed characteristics. Monthly Manning's roughness and depression depth data can be specified for



each subcatchment. However, monthly evaporation coefficients can be only specified in the entire simulation area due to the assumed small changes of evaporation rates between each subcatchment.

4.3 Pollutant Buildup/Washoff Data

As described above, the generalized pollutant buildup and washoff equations are used for the water quality simulation in SRPM. Monthly values of the maximum buildup value (lbs-ac-day), buildup rate (1/day), washoff coefficient (1/inch), and washoff exponent are the input data for the water quality simulation. Both pollutant buildup and washoff input parameters are often used as the model calibration parameters. The input format of the pollutant build up and washoff data is shown in Appendix A.

5. MODEL OUTPUT

5.1 Time Series Output

Four time-series output files are generated from SRPM: hourly, daily, monthly and annual simulation results. All output files provide runoff (in) and pollutant concentrations (Appendix C). The output files are in ASCII time-series format which is easy to use for further data analysis and graphical display and can be directly linked into a GIS platform.

5.2 Other Simulation Outputs

Besides time-series simulation results, the model also provides an hourly time step mass balance file. The mass balance file is created for checking the water budget in a time step or at the end of the simulation period. It consists of eight components: (1) PREC – amount of rainfall; (2) INF1 – water infiltrated into groundwater; (3) EVAP – water loss due to evaporation;



(4) RUNO – runoff from watershed; (5) WREM – water remaining in watershed at the end of simulation time; (6) CUMI – cumulative water amount of precipitation; (7) CUMO – cumulative water loss, including infiltration, evaporation, and runoff; and (8) ERRO – percentage error of cumulative rainfall versus cumulative water loss (Appendix C).

Another simulation output is the geometric and hydraulic data used for the simulation of hydrologic flow routing. At each simulation run, the model will generate one geometric and hydraulic data file for each subcatchment. The format of the output file is provided in Appendix C. Huber et al (1987) described more information about the reservoir hydrologic routing method and the parameters used for the method.

6. MODEL PACKAGE

6.1 Programs and Input/Output Files

FORTRAN programs, input files, and output files which come with the SRPM model package are shown in Table 1.

Table 1. Components of SRPM Model Package

Component	File Name	Description
Programs	srpm1_3.f	FORTRAN source code of main program, Version 1.3
	srpm	executable file of the SRPM model
	convert.f	FORTRAN source code for converting daily to hourly evaporation data
	convert	executable file of the conversion program



Input Files	precipi.inp	hourly precipitation data (in)
	evapora.hor	hourly pan evaporation data (in)
	watershe.inp	watershed and pollutant buildup/washoff data
Output Files	srpm_hrc.out	hourly runoff (in) and pollutant concentrations (mg/l)
	srpm_day.out	daily runoff (in) and pollutant concentrations (mg/l)
	srpm_mon.out	monthly runoff (in) and pollutant concentrations (mg/l)
	srpm_ann.out	annual runoff (in) and pollutant concentrations (mg/l)
	massbala.out	hourly water budget balance data (in)
	wat_flw1.dat "	geometric and hydraulic data for subcatchment 1 "
	wat_flw9.dat wat_flw10.dat	geometric and hydraulic data for subcatchment 9 geometric and hydraulic data for subcatchment 10

6.2 Computer Requirements

The programs that come with SRPM were written in standard FORTRAN language. A workstation which has a FORTRAN compiler that is compatible with the operating system is needed. The model was developed and tested under the UNIX operating system on a SUN SPARC



workstation.

The minimum configuration for a PC is an 80386 IBM compatible with a math coprocessor. A FORTRAN compiler for the PC is needed to compile SRPM. Two megabytes of memory or greater are required. The free hard disk space required depends on the simulation period. A minimum of 15 Mb is recommended for a 3-year simulation.

ACKNOWLEDGMENTS

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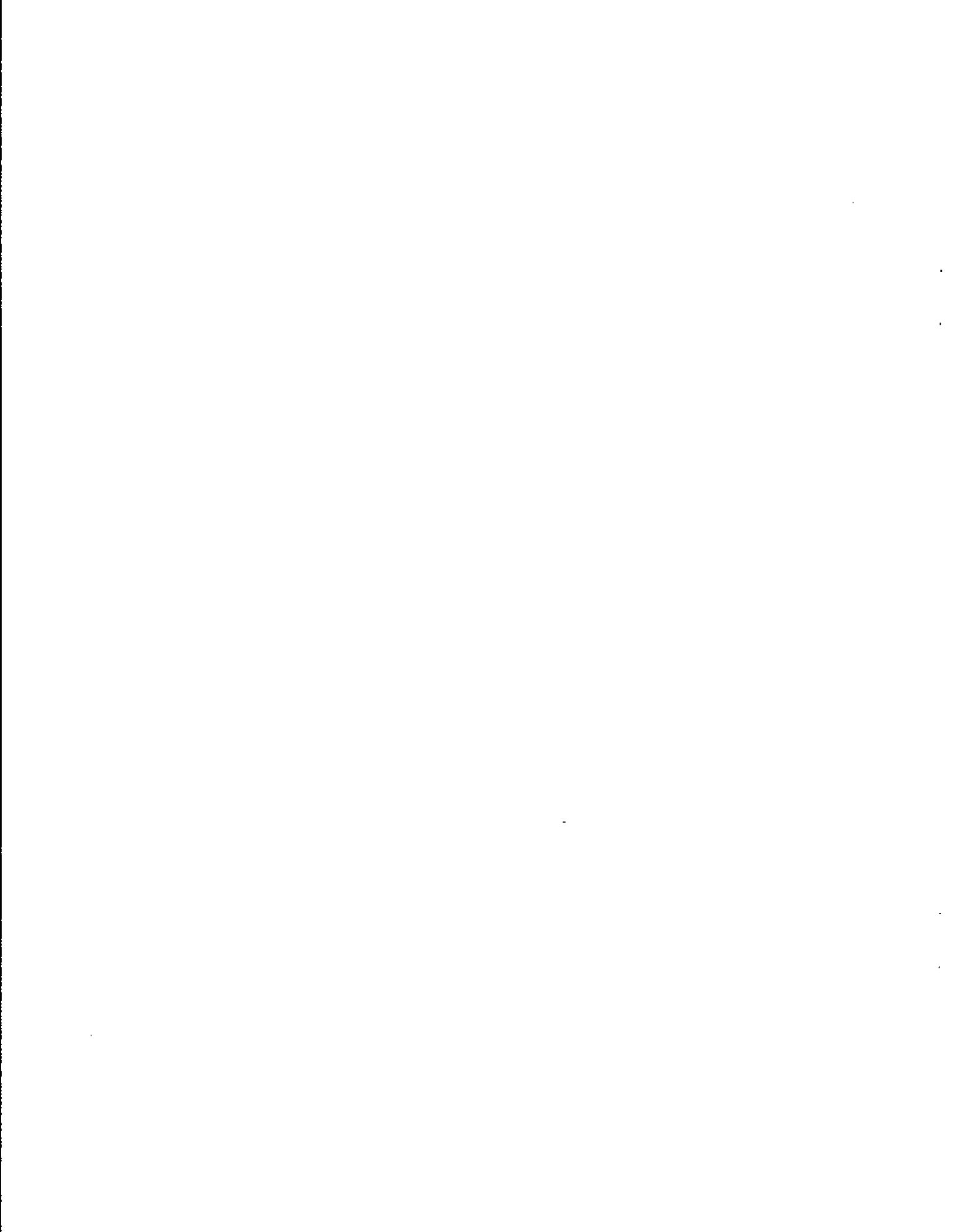
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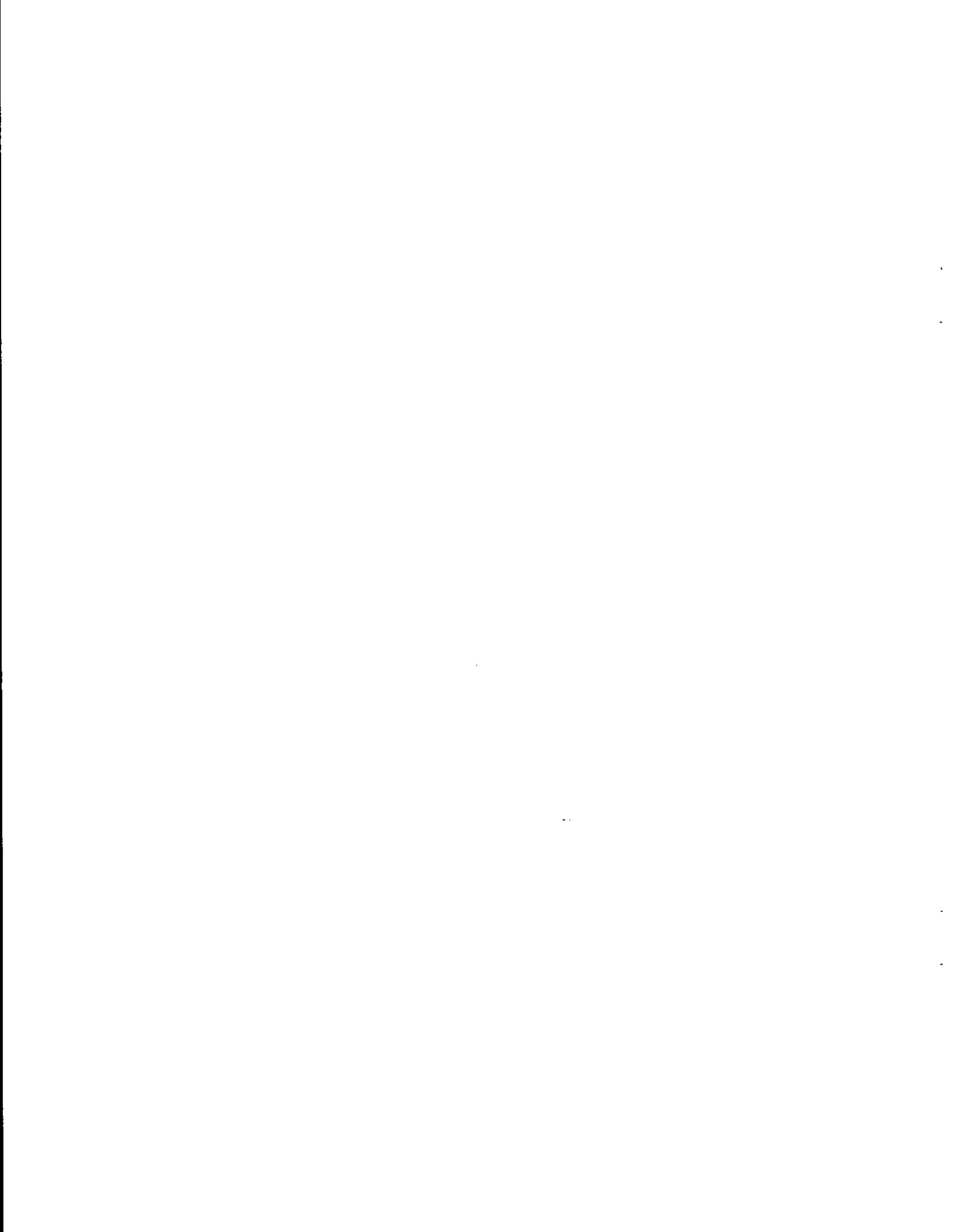
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APPENDIX A
SRPM INPUT

APPENDIX A-1

Hourly Precipitation Data

Dec 13 16:32

precipi.imp

1

WET	1991	7	12	7	0	0.0000000000
WET	1991	7	12	8	0	0.0000000000
WET	1991	7	12	9	0	0.0000000000
WET	1991	7	12	10	0	0.0000000000
WET	1991	7	12	11	0	0.0000000000
WET	1991	7	12	12	0	0.1100000000
WET	1991	7	12	13	0	0.0500000000
WET	1991	7	12	14	0	0.0000000000
WET	1991	7	12	15	0	0.3900000000
WET	1991	7	12	16	0	0.2200000000
WET	1991	7	12	17	0	0.1400000000
WET	1991	7	12	18	0	0.0100000000
WET	1991	7	12	19	0	0.0000000000
WET	1991	7	12	20	0	0.0100000000
WET	1991	7	12	21	0	0.0000000000
WET	1991	7	12	22	0	0.0000000000
WET	1991	7	12	23	0	0.0000000000
WET	1991	7	12	24	0	0.0000000000
WET	1991	7	13	1	0	0.0000000000
WET	1991	7	13	2	0	0.0000000000
WET	1991	7	13	3	0	0.0000000000
WET	1991	7	13	4	0	0.0000000000
WET	1991	7	13	5	0	0.0000000000
WET	1991	7	13	6	0	0.0000000000
WET	1991	7	13	7	0	0.0000000000
WET	1991	7	13	8	0	0.0000000000
WET	1991	7	13	9	0	0.0000000000
WET	1991	7	13	10	0	0.0100000000
WET	1991	7	13	11	0	1.3100000000
WET	1991	7	13	12	0	0.4100000000
WET	1991	7	13	13	0	0.2300000000
WET	1991	7	13	14	0	0.1300000000
WET	1991	7	13	15	0	0.0000000000
WET	1991	7	13	16	0	0.0100000000
WET	1991	7	13	17	0	0.0000000000
WET	1991	7	13	18	0	0.0000000000
WET	1991	7	13	19	0	0.0000000000
WET	1991	7	13	20	0	0.0000000000
WET	1991	7	13	21	0	0.0000000000
WET	1991	7	13	22	0	0.0000000000
WET	1991	7	13	23	0	0.0000000000
WET	1991	7	13	24	0	0.0000000000
WET	1991	7	14	1	0	0.0000000000
WET	1991	7	14	2	0	0.0000000000
WET	1991	7	14	3	0	0.0000000000
WET	1991	7	14	4	0	0.0000000000
WET	1991	7	14	5	0	0.0000000000
WET	1991	7	14	6	0	0.0000000000
WET	1991	7	14	7	0	0.0000000000
WET	1991	7	14	8	0	0.0000000000
WET	1991	7	14	9	0	0.0400000000
WET	1991	7	14	10	0	0.4600000000
WET	1991	7	14	11	0	0.0300000000
WET	1991	7	14	12	0	0.0100000000
WET	1991	7	14	13	0	0.0000000000
WET	1991	7	14	14	0	0.0000000000
WET	1991	7	14	15	0	0.1100000000
WET	1991	7	14	16	0	0.0500000000
WET	1991	7	14	17	0	0.0000000000
WET	1991	7	14	18	0	0.0000000000
WET	1991	7	14	19	0	0.0000000000
WET	1991	7	14	20	0	0.0000000000
WET	1991	7	14	21	0	0.0000000000
WET	1991	7	14	22	0	0.0000000000
WET	1991	7	14	23	0	0.0000000000

APPENDIX A-2

Hourly Pan Evaporation Data

EVA	1991	5	1	1	0	0.000000000
EVA	1991	5	1	2	0	0.000000000
EVA	1991	5	1	3	0	0.000000000
EVA	1991	5	1	4	0	0.000000000
EVA	1991	5	1	5	0	0.000000000
EVA	1991	5	1	6	0	0.002694790
EVA	1991	5	1	7	0	0.007532608
EVA	1991	5	1	8	0	0.012370427
EVA	1991	5	1	9	0	0.015860850
EVA	1991	5	1	10	0	0.015860850
EVA	1991	5	1	11	0	0.015860850
EVA	1991	5	1	12	0	0.015860850
EVA	1991	5	1	13	0	0.015860850
EVA	1991	5	1	14	0	0.015860850
EVA	1991	5	1	15	0	0.015860850
EVA	1991	5	1	16	0	0.012370426
EVA	1991	5	1	17	0	0.007532608
EVA	1991	5	1	18	0	0.002694789
EVA	1991	5	1	19	0	0.000000000
EVA	1991	5	1	20	0	0.000000000
EVA	1991	5	1	21	0	0.000000000
EVA	1991	5	1	22	0	0.000000000
EVA	1991	5	1	23	0	0.000000000
EVA	1991	5	1	24	0	0.000000000
EVA	1991	5	2	1	0	0.000000000
EVA	1991	5	2	2	0	0.000000000
EVA	1991	5	2	3	0	0.000000000
EVA	1991	5	2	4	0	0.000000000
EVA	1991	5	2	5	0	0.000000000
EVA	1991	5	2	6	0	0.002743248
EVA	1991	5	2	7	0	0.007563240
EVA	1991	5	2	8	0	0.012383234
EVA	1991	5	2	9	0	0.015831603
EVA	1991	5	2	10	0	0.015831603
EVA	1991	5	2	11	0	0.015831603
EVA	1991	5	2	12	0	0.015831603
EVA	1991	5	2	13	0	0.015831603
EVA	1991	5	2	14	0	0.015831603
EVA	1991	5	2	15	0	0.015831603
EVA	1991	5	2	16	0	0.012383234
EVA	1991	5	2	17	0	0.007563240
EVA	1991	5	2	18	0	0.002743248
EVA	1991	5	2	19	0	0.000000000
EVA	1991	5	2	20	0	0.000000000
EVA	1991	5	2	21	0	0.000000000
EVA	1991	5	2	22	0	0.000000000
EVA	1991	5	2	23	0	0.000000000
EVA	1991	5	2	24	0	0.000000000
EVA	1991	5	3	1	0	0.000000000
EVA	1991	5	3	2	0	0.000000000
EVA	1991	5	3	3	0	0.000000000
EVA	1991	5	3	4	0	0.000000000
EVA	1991	5	3	5	0	0.000000000
EVA	1991	5	3	6	0	0.002790787
EVA	1991	5	3	7	0	0.007593253
EVA	1991	5	3	8	0	0.012395720
EVA	1991	5	3	9	0	0.015802793
EVA	1991	5	3	10	0	0.015802793
EVA	1991	5	3	11	0	0.015802793
EVA	1991	5	3	12	0	0.015802793
EVA	1991	5	3	13	0	0.015802793
EVA	1991	5	3	14	0	0.015802793
EVA	1991	5	3	15	0	0.015802793
EVA	1991	5	3	16	0	0.012395721
EVA	1991	5	3	17	0	0.007593255
EVA	1991	5	3	18	0	0.002790787
EVA	1991	5	3	19	0	0.000000000
EVA	1991	5	3	20	0	0.000000000
EVA	1991	5	3	21	0	0.000000000
EVA	1991	5	3	22	0	0.000000000
EVA	1991	5	3	23	0	0.000000000

APPENDIX A-3

Watershed Data and Pollutant Buildup/Washoff Data

	Input Data for SRPM - Version 1.3				
Subcatchment #	1	2	3	4	5
Land Use Type	COMME				
Area (acres)	15.32				
Width (ft)	817.				
Slope (ft/ft)	0.001				
Max Inf. Rate (mm/h)	2.0				
Min Inf. Rate (mm/h)	0.5				
Decay Param. (1/min)	0.9				
Infil. Regen. Ratio	0.01				
Hornr-1/Green-Ampt-2	1				
Capill. Suction (ft)	0.70				
Moi. Deficit (ft/ft)	0.26				
Sat Hyd. Cond.(ft/h)	0.0038				
P Added (kg/ha/day)	0.120				
P in S. Water-kg/ha	0.00				
P on Top Soil-kg/ha	10.00				

Phosphorus Coeff. PCRAIN-mg/L EFFPRAIN-1/cm EFFPRUNO-1/cm
0.1 0.0700 0.1200

Evaporation Coeff.	J	F	M	A	M	J	J	J	A	S	O	N	D
	.70	.70	.70	.75	.80	.85	.85	.85	.75	.75	.75	.75	.75

Manning's roughness J F M A M J S O N D
 1st subcatchment .015 .020 .020 .013 .025 .015 .020 .010 .005 .010 .010 .020

Depression depth J F M A M J J A S O N D
1st subcatchment-in .01 .01 .01 .01 .01 .010 .01 .020 .001 .010 .01 .01

APPENDIX B
FORTRAN PROGRAMS

APPENDIX B-1

Program to Convert Daily to Hourly Evaporation Data

Dec 13 15:29

convert.f

1

C This program is intended to convert daily evaporation data (in) to the
C hourly format for the SWRPLM model input by using a HSPP subroutine.
C File: 'convert_daily_hourly.f' (01/25/95).
C
REAL DRD, JDAY, RDIST(24), ALAT
INTEGER YEAR, MON, DAY, I
OPEN (1, FILE='evapora.inp')
OPEN (2, FILE='evapora.hor')

JDAY = 90.0
* 2*3.14159/360 = 0.0174582
ALAT = 27.5
ALAT = ALAT * 0.0174582
5 READ (1, 20, END = 1000) YEAR, MON, DAY, DRD
20 FORMAT (6X,I4,1X,2(I2,1X),3X,F13.0)
30 FORMAT (1X,A1,2X,I4,1X,4(I2,1X),F13.9)

IF (JDAY .GE. 365) JDAY = 0.0
JDAY = JDAY + 1.0

CALL RAD (ALAT, JDAY, DRD, RDIST)

DO I =1, 24
WRITE (2, 30) 'EVA', YEAR, MON, DAY, I, 0, RDIST(I)
ENDDO
GOTO 5

1000 CLOSE (1)
CLOSE (2)
STOP
END

SUBROUTINE RAD (ALAT, JDAY, DRD, RDIST)
C COMPUTES HSPP QUALITY HOURLY RADIATION DISTRIBUTION GIVEN
C LATITUDE, ALAT(IN RADIANS), JDAY(JULIAN DAY OF YEAR) AND
C DAILY RADIATION.
C
C ARGUMENTS
REAL ALAT, DRD, JDAY, RDIST(24)
REAL PHI, AD, SS, CS, X2, DELT, SUNR, SUNS, DTR2, DTR4, CRAD, SL, TRISE
REAL TR2, TR4, RK
INTEGER IK
PHI=ALAT
AD= 0.40928*COS(0.0172141*(172.-JDAY))
SS= SIN(PHI)*SIN(AD)
CS=COS(PHI)*COS(AD)
X2=-SS/CS
DELT=7.6394*(1.5708-ATAN(X2/SQRT(1.-X2**2)))
SUNR=12.-DELT/2.
SUNS=12.+DELT/2.
C DEVELOP HOURLY DISTRIBUTION GIVEN SUNRISE, SUNSET AND LENGTH
C OF DAY (DELT)
DTR2= DELT/2.
DTR4= DELT/4.
CRAD= .66666667/DTR2
SL= CRAD/DTR4
TRISE= SUNR
TR2= TRISE+DTR4
TR3= TR2+DTR2
TR4= TR3+DTR4
DO 100 IK=1, 24
RK=REAL(IK)
IF (RK.LE.TRISE) GO TO 90
IF (RK.LE.TR2) GO TO 80
IF (RK.LE.TR3) GO TO 70
IF (RK.LE.TR4) GO TO 60
RDIST(IK)=0.0
GO TO 65
60 CONTINUE
RDIST(IK)=(CRAD-(RK-TR3)*SL)*DRD
65 CONTINUE
GO TO 75
70 CONTINUE
RDIST(IK)=CRAD*DRD
75 CONTINUE
GO TO 85
80 CONTINUE
RDIST(IK)=(RK-TRISE)*SL*DRD
85 CONTINUE
GO TO 95
90 CONTINUE

Dec 13 15:29

convert.f

2

```
      RDIST(IK)=0.0
95    CONTINUE
100   CONTINUE
      RETURN
      END
```

APPENDIX B-2

Main Program of the SRPM Model

#1101_3.3

Page 13 16:44

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Dec 13 16:44

Dec 13 16:44

step1_3.f

10

```

EROF
IF (P0003(1) .LT. 0.0001) P0003(1) = 0.0
**** Total water loss due to evap - inf(1), and runoff ****

```

```

W05T1(1) = A_EROF(1) * R_EROF(1) + P0003(1),

```

```

TR05G = TR05M + R05G(1) * AREAS(1)
W05G2 = W05G2 + RE5T1(1) * AREAS(1)
S_ERF2 = S_ERF2 + A_ERF1(1) * AREAS(1)
S_ERF2 = S_ERF2 + A_ERF2(1) * AREAS(1)
S_WRF2 = S_WRF2 + R05W(1) * AREAS(1)
S_WRF2 = S_WRF2 + R05W(1) * AREAS(1)
C_WRF2 = C_WRF2 + R05W(1) * AREAS(1)

```

```
EROF
```

```
R05G(2) = YL05G / TAREAS
```

```

R05T1(2) = W05T1(1) * TR05G / TAREAS
S_ERF2 = S_ERF2 / TAREAS
S_WRF2 = S_WRF2 / TAREAS
S_WRF2 = S_WRF2 / TAREAS

```

```

C_WRF2 = C_WRF1 * R05G
C_WRF2 = C_WRF2 * W05G

```

```

IF (C_WRF2 .GT. 0.0) THEN
  T0001 = (C_WRF2 - C_WRF1) / C_WRF2 * 300.
  ELSE
    EROR1 = 0.0
  ENDIF

```

```

***** Calculate pollutant buildup (mg) ****
DO J = 1, N_LAND
  IF (P0001(J) .LE. 0.0005) THEN
    DO J = 1, N_TW
      P0011(J,J) = P0011(J,J) * P_TW(J,J) / T0001
      4.5365 * (1.0 - EXP(-T0001(J,J) / 24.0))
    ENDIF

```

```

***** Calculate pollutant buildup (mg) ****
DO J = 1, N_TW
  IF (P0001(J) .LE. 0.0005) THEN
    DO J = 1, N_LAND
      P0011(J,J) = P0011(J,J) * P_TW(J,J) / T0001
      4.5365 * (1.0 - EXP(-T0001(J,J) / 24.0))
    ENDIF

```

```

***** Calculate the retained pollutant load in subcatchment after washoff ****
DO J = 1, N_TW
  IF (P0001(J,J) .GT. 0.0 AND. P0001(J,J) .GE. 0.01) THEN
    P0011(J,J) = P0011(J,J) * EXP(-0.5 * WASH(J,J) * DELT_T)
    (EXP(0.5 * WASH(J,J)) * LOG(WASH(J,J)) / 1111 +
     EXP(0.5 * WASH(J,J)) * LOG(WASH(J,J)) / 1111)
    write(*,*) P0011(J,J), J, log10(A(J,J)), log10(B(J,J)), delt_t,
    B(J,J), A(J,J), log10(C(J,J)), log10(D(J,J)))
  ELSE IF (P0001(J,J) .GT. 0.0) THEN
    P0011(J,J) = P0011(J,J) * EXP(-0.5 * WASH(J,J) * DELT_T)
    (EXP(0.5 * WASH(J,J)) * LOG(WASH(J,J)) / 1111 +
     EXP(0.5 * WASH(J,J)) * LOG(WASH(J,J)) / 1111)
  ELSE IF (P0001(J,J) .GT. 0.0) THEN
    P0011(J,J) = P0011(J,J) * EXP(-0.5 * WASH(J,J) * DELT_T)
    (EXP(0.5 * WASH(J,J)) * LOG(WASH(J,J)) / 1111 +
     EXP(0.5 * WASH(J,J)) * LOG(WASH(J,J)) / 1111)
  ENDIF

```

```

***** Apply different method for TW movement in agricultural area that used
**** in P0001 ****

```

```

IF (WASH(J,J) .GE. 1.0) THEN
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
  Z_S2
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)

```

```

***** Calculate sum of daily, monthly, area annual results ****

```

```

DO J = 1, N_LAND
  IF (WASH(J,J) .GE. 1.0) THEN
    P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
    P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
    P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
    P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
  ENDIF

```

```

***** Print out hourly simulation results ****

```

```

C_WRITE(1,*) P0011(1,1), P0011(1,1), P0011(1,1), C_F05G(1)

```

```

***** Task 3: Output Results ****

```

```

C_WRITE(1,*) '-----'
C_WRITE(1,*) '-----'
C_WRITE(1,*) '-----'
C_WRITE(1,*) '-----'
C_WRITE(1,*) '-----'

```

```

***** Print out hourly simulation results ****

```

```

C_WRITE(1,1501) 'HRS' 1900*YEAR1,MON1,DAY1,HR1,D_RUNOFF1,
C_WRITE(1,1501) 'HRS' 1900*YEAR1,MON1,DAY1,HR1,D_FRECL_S,F05P1,
C_WRITE(1,1501) 'HRS' 1900*YEAR1,MON1,DAY1,HR1,D_FRECL_S,F05P1,
C_WRITE(1,1501) 'HRS' 1900*YEAR1,MON1,DAY1,HR1,D_FRECL_S,F05P1

```

```

***** Record 1351 ***** RECORD 1351 ***** RECORD 1351 ***** RECORD 1351 ****

```

```

N0TE(1351) RECORD,1351,MON1,CDF1,HR1,R05P1,
N0TE(1351) RECORD,1351,MON1,CDF1,HR1,R05P1,
RECORD = RECORD + 1

```

```

***** Calculate sum of daily, monthly, area annual results ****

```

```

D_R05P0 = D_R05P0 + R05P0
D_R05P1 = D_R05P1 + R05P1
A_R05P0 = A_R05P0 + R05P0
A_R05P1 = A_R05P1 + R05P1

```

```

DO J = 1, N_TW
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)
  P0011(J,J) = P0011(J,J) * (1.0 - 0.5 * WASH(J,J) * DELT_T)

```

```

***** Print out hourly simulation results ****

```

```
END
```

```

Dec 13 16:44

step1.3.f

if (readfrom(26280),eq.0, and, comml1.eq.1) WRITE(*,180)*
 10 % simulation completed
  if (readfrom(26280),neq.0, and, comml1.eq.2) WRITE(*,180)*
 20 % simulation completed
    if (readfrom(26280),eq.0, and, comml1.eq.3) WRITE(*,180)*
      30 % simulation completed
        if (readfrom(26280),eq.0, and, comml1.eq.4) WRITE(*,180)*
          40 % simulation completed
            if (readfrom(26280),eq.0, and, comml1.eq.5) WRITE(*,180)*
              50 % simulation completed
                if (readfrom(26280),eq.0, and, comml1.eq.6) WRITE(*,180)*
                  60 % simulation completed
                    if (readfrom(26280),eq.0, and, comml1.eq.7) WRITE(*,180)*
                      70 % simulation completed
                        if (readfrom(26280),eq.0, and, comml1.eq.8) WRITE(*,180)*
                          80 % simulation completed
                            if (readfrom(26280),eq.0, and, comml1.eq.9) WRITE(*,180)*
                              90 % simulation completed
                                **** Initiate some variables for next time step calculation ****

```

Page 13 of 14

Dec 13 16:44

11

ETPM1_3.E

•1001_1-1

APPENDIX C
SRPM OUTPUT

APPENDIX C-1

Hourly Runoff and Pollutant Concentrations

APPENDIX C-2

Daily Runoff and Pollutant Concentrations

Dec 13 16:52

srpm_day.out

REC	YEAR	MONTH	DAY	RJNG	BODS	TSS	TM	TP	ZM	PEST	TRAC	PB	CU
45	1991	6,14,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
46	1991	6,15,	0	0.04223,	0.009229,	0.563043,	0.02544,	0.02519,	0.00223,	0.00229,	0.336864,	0.00229,	0.000000,
47	1991	6,16,	0	0.067518,	0.001845,	4.527112,	0.042909,	0.019808,	0.001845,	0.001845,	2.716544,	0.001845,	0.000000,
48	1991	6,17,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
49	1991	6,18,	0	0.581005,	0.014186,	34.806637,	0.322291,	0.146544,	0.014186,	0.014186,	0.014186,	0.014186,	0.000000,
50	1991	6,19,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
51	1991	6,20,	0	0.057444,	0.001622,	3.979306,	0.035773,	0.015984,	0.001622,	0.001622,	2.387973,	0.001622,	0.000000,
52	1991	6,21,	0	0.465126,	0.010376,	25.460407,	0.226312,	0.100381,	0.010376,	0.010376,	15.276299,	0.010376,	0.000000,
53	1991	6,22,	0	0.029075,	0.004564,	11.198627,	0.099540,	0.04153,	0.004564,	0.004564,	6.718966,	0.004564,	0.000000,
54	1991	6,23,	0	0.006530,	0.000346,	0.849562,	0.067915,	0.003240,	0.000346,	0.000346,	0.510360,	0.000346,	0.000000,
55	1991	6,24,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
56	1991	6,25,	0	0.493411,	0.012438,	30.517471,	0.258052,	0.110633,	0.012438,	0.012438,	18.310507,	0.012438,	0.000000,
57	1991	6,26,	0	0.036159,	0.006802,	16.696149,	0.141133,	0.060566,	0.006802,	0.006802,	10.014033,	0.006802,	0.000000,
58	1991	6,27,	0	0.016492,	0.000876,	2.150113,	0.017818,	0.007530,	0.000876,	0.000876,	1.298069,	0.000876,	0.000000,
59	1991	6,28,	0	0.000248,	0.000020,	0.082051,	0.000641,	0.000160,	0.000020,	0.000020,	0.041927,	0.000020,	0.000000,
60	1991	6,29,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
61	1991	6,30,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
62	1991	7,1,	0	0.617900,	0.012269,	30.104082,	0.237102,	0.096464,	0.012269,	0.012269,	18.062410,	0.012269,	0.000000,
63	1991	7,2,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
64	1991	7,3,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
65	1991	7,4,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
66	1991	7,5,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
67	1991	7,6,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
68	1991	7,7,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
69	1991	7,8,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
70	1991	7,9,	0	0.365309,	0.000338,	0.830788,	0.006612,	0.002256,	0.000338,	0.000338,	0.497707,	0.000338,	0.000000,
71	1991	7,10,	0	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,	0.000000,
72	1991	7,11,	0	0.153520,	0.006666,	16.356247,	0.116492,	0.043302,	0.006666,	0.006666,	9.813629,	0.006666,	0.000000,

1

APPENDIX C-3

Monthly Runoff and Pollutant Concentrations

APPENDIX C-4

Annual Runoff and Pollutant Concentrations

Dec 13 16:54

srpm_ann.out

1

"REC"	"YEAR"	"RUNO"	"BOD5"	"TSS"	"TN"	"TP"	"ZN"	"PESF"	"TRAC"	"PB"	"CU"
1,1991,	7.737563,	0.014554,	35.712685,	0.483337,	0.240408,	0.014554,	0.014554,	21.427322,	0.014554,	0.014554,	0.014554,
2,1992,	17.938952,	0.041928,	102.887016,	0.915421,	0.383678,	0.041928,	0.041928,	61.735802,	0.041928,	0.041928,	0.041928,
3,1993,	21.672411,	0.031141,	76.409767,	0.672247,	0.273983,	0.031141,	0.031141,	45.844948,	0.031141,	0.031141,	0.031141,

APPENDIX C-5

Hourly Mass Balance Data

APPENDIX C-6

Geometric and Hydraulic Data

Geometric and Hydraulic Data - Storage Facility

Depth FT	Area FT ²	Vol-V2 FT ³	Overflow CFS	Disc-0 CF	AVG_O2T FT ³	AVG_O2T+V2 FT ³
0.00E+00	0.67E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
0.28E-03	0.67E+06	0.19E+03	0.00E+00	0.00E+00	0.00E+00	0.19E+03
0.56E-03	0.67E+06	0.37E+03	0.00E+00	0.00E+00	0.00E+00	0.37E+03
0.83E-03	0.67E+06	0.56E+03	0.00E+00	0.00E+00	0.00E+00	0.56E+03
0.12E+00	0.67E+06	0.78E+05	0.27E+01	0.00E+00	0.49E+04	0.62E+05
0.23E+00	0.67E+06	0.15E+06	0.87E+01	0.00E+00	0.16E+05	0.17E+06
0.35E+00	0.67E+06	0.23E+06	0.17E+02	0.00E+00	0.31E+05	0.26E+06
0.46E+00	0.67E+06	0.31E+06	0.27E+02	0.00E+00	0.49E+05	0.36E+06
0.58E+00	0.67E+06	0.39E+06	0.40E+02	0.00E+00	0.72E+05	0.46E+06
0.69E+00	0.67E+06	0.46E+06	0.54E+02	0.00E+00	0.97E+05	0.56E+06
0.81E+00	0.67E+06	0.54E+06	0.70E+02	0.00E+00	0.13E+06	0.67E+06
0.92E+00	0.67E+06	0.62E+06	0.87E+02	0.00E+00	0.16E+06	0.77E+06
0.10E+01	0.67E+06	0.69E+06	0.11E+03	0.00E+00	0.19E+06	0.88E+06
0.12E+01	0.67E+06	0.77E+06	0.13E+03	0.00E+00	0.23E+06	0.10E+07
0.13E+01	0.67E+06	0.85E+06	0.15E+03	0.00E+00	0.27E+06	0.11E+07
0.14E+01	0.67E+06	0.92E+06	0.17E+03	0.00E+00	0.31E+06	0.12E+07
0.15E+01	0.67E+06	0.10E+07	0.20E+03	0.00E+00	0.35E+06	0.14E+07
0.16E+01	0.67E+06	0.11E+07	0.22E+03	0.00E+00	0.40E+06	0.15E+07
0.17E+01	0.67E+06	0.12E+07	0.25E+03	0.00E+00	0.45E+06	0.16E+07
0.18E+01	0.67E+06	0.12E+07	0.28E+03	0.00E+00	0.50E+06	0.17E+07
0.20E+01	0.67E+06	0.13E+07	0.31E+03	0.00E+00	0.55E+06	0.19E+07
0.21E+01	0.67E+06	0.14E+07	0.34E+03	0.00E+00	0.61E+06	0.20E+07
0.22E+01	0.67E+06	0.15E+07	0.37E+03	0.00E+00	0.66E+06	0.21E+07
0.23E+01	0.67E+06	0.15E+07	0.40E+03	0.00E+00	0.72E+06	0.23E+07
0.24E+01	0.67E+06	0.16E+07	0.44E+03	0.00E+00	0.78E+06	0.24E+07
0.25E+01	0.67E+06	0.17E+07	0.47E+03	0.00E+00	0.85E+06	0.25E+07
0.27E+01	0.67E+06	0.18E+07	0.51E+03	0.00E+00	0.91E+06	0.27E+07
0.28E+01	0.67E+06	0.18E+07	0.54E+03	0.00E+00	0.98E+06	0.28E+07
0.29E+01	0.67E+06	0.19E+07	0.58E+03	0.00E+00	0.10E+07	0.30E+07
0.30E+01	0.67E+06	0.20E+07	0.62E+03	0.00E+00	0.11E+07	0.31E+07

